MODIFICATION OF COIR FIBER AS POLYMER REINFORCEMENT

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ABSTRACT

Studies on the use of natural fibers as replacement to man-made fiber in fiber-reinforced composites have increased and opened up further industrial possibilities. This research will enhance the usage of composite in industrial application and also in household product. The objectives of this research are to modify the surface property of coir fiber and to study the bonding mechanism between the coir fiber and the polymer. In order to achieve the objective, there are several steps have been done during the research that is the surface treatment of fiber by NaOH solution with manipulated concentration, composites production with epoxy resin and coir fiber as the reinforcement and also the characterization of the composites. The process flows of this research are the fiber preparation, stock solution preparation, fiber treatment, fiber testing, polymer preparation, and polymer testing. From the result, untreated coir fiber has Kappa number of 46.75, 20% NaOH treated fiber has Kappa number of 32.63, 25% NaOH treated fiber has Kappa number of 28.86, and 30% NaOH treated fiber has Kappa number of 20.09. The treatment have made the fiber more thermal resistant as approved by the increase in the decomposition temperature of coir fiber and also increase in weight percent remaining at specific temperature that is at 300°C. For untreated fiber, it have decomposition temperature of 336.64°C while for 20%NaOH treated fiber, the decomposition temperature is 366.13°C. From the results also, increasing in NaOH concentration has result in increasing tensile strength of the composite and the optimum concentration for the highest tensile strength is at 25% NaOH treated fiber. The conclusion that have been made is the alkali treatment have been successfully done and renewable fibers like coir can be used as reinforcing materials for low cost composites, due to the economic and environmental advantages of such materials.

ABSTRAK

Kajian mengenai penggunaan serat alam sebagai pengganti serat buatan manusia dalam komposit serat-diperkuatkan telah meningkat dan membuka kemungkinan industri dengan lebih lanjut. Penelitian ini akan meningkatkan penggunaan komposit dalam aplikasi industri dan juga dalam produk rumah tangga. Tujuan dari penelitian ini adalah untuk mengubahsuai sifat permukaan serat sabut dan mempelajari mekanisme ikatan antara gentian sabut dan polimer. Untuk mencapai tujuan tersebut, ada beberapa langkah telah dilakukan selama penelitian iaitu merawat permukaan serat dengan larutan NaOH dengan kepekatan yang dimanipulasi, penghasilan komposit dengan resin epoksi dan serat sabut sebagai penguat dan juga ujian terhadap komposit. Proses yang terlibat dalam kajian ini adalah persiapan serat, persiapan larutan kimia, rawatan serat, ujian ke atas serat, persiapan polimer, dan ujian ke atas polimer. Dari hasil kajian, serat sabut tidak dirawat mempunyai nombor Kappa sebanyak 46.75, manakala rawatan 20% NaOH ke atas serat mempunyai nombor Kappa sebanyak 32.63, rawatan 25% NaOH ke atas serat pula mempunyai nombor Kappa sebanyak 28.86, dan rawatan 30% NaOH ke atas serat pula mempunyai nombor Kappa sebanyak 20.09. Rawatan NaOH telah membuat serat lebih tahan panas yang dibuktikan oleh peningkatan suhu penguraian serat sabut dan juga peningkatan peratus berat sisa pada suhu tertentu iaitu pada 300°C. Untuk serat tidak dirawat, ia memiliki suhu penguraian sebanyak 336.64°C, sedangkan untuk rawatan 20% NaOH ke atas serat, suhu penguraian ialah 366.13°C. Dari hasil kajian juga, peningkatan kepekatan NaOH telah menghasilkan peningkatan kekuatan ketegangan komposit dan kepekatan optimum untuk kekuatan ketegangan tertinggi adalah rawatan 25% NaOH ke atas serat. Kesimpulan yang telah dibuat adalah rawatan alkali telah berjaya dilakukan dan serat sabut boleh digunakan sebagai bahan penguat untuk komposit kos rendah, kerana keuntungan ekonomi dan kelebihan terhadap persekitaran dari bahan tersebut.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS & SYMBOLS

%	-	Percentage
wt%	-	Weight percent
cm	-	Centimeter
DP	-	Degree of polymerization
g	-	Gram
kg	-	Kilo Gram
kN	-	Kilo Newton
m	-	Meter
ml	-	Milliliter
mm	-	Millimeter
N	-	Normality
NaOH	-	Sodium Hydroxide
OH	-	Hydroxide
^{o}C	-	Degree Celsius
Pa	-	Pascal
TAPPI	-	Technical Association of the Pulp and Paper Industry
V	-	Volume
SEM	-	Scanning Electron Microscopy

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CHAPTER 1

INTRODUCTION

1.1 Research Background

From being an importer of petrochemicals, Malaysia is today an exporter of major petrochemical products. A wide range of petrochemicals are produced in Malaysia such as olefins, polyolefin, aromatics, ethylene oxides, glycols, oxo-alcohols, exthoxylates, acrylic acids, phthalic anhydride, acetic acid, styrene monomer, high impact polystyrene, ethyl benzene, vinyl chloride monomer and polyvinyl chloride and polybutylene terephthalate. These world scale plants have also contributed significantly to the development of local downstream plastic processing activities by providing a steady supply of feedstock material for the plastic industry.

These factors have led the plastic products industry to become one of the most dynamic industries in Malaysia's manufacturing sector. The plastic industry can be divided into four sub-sectors, namely packaging sub-sector, electrical & electronics and automotive components sub-sector, consumer and industrial products sub-sector and others. The packaging sub-sector, both flexible and rigid (including bags, films, bottles and containers), remains the largest market for the plastic

industry. The main production processes involved in the plastic producers industry are injection molding, pipes and profiles extrusion and foam molding.

There are more than 1,550 companies in operation, producing products ranging from common household items, packaging materials and conveyance articles to parts and components for the electrical and electronics, automotive, office automation, computer and telecommunications industries.

Malaysia is currently a net exporter of plastic products. The total export of plastic products amounted to RM9.34 billion in 2008, an increased of 11.5 per cent compared with 2007. The main products exported were containers of plastics, plates, films, sheets, foils, strips and other articles of plastics. The main export destinations included the EU, the People's Republic of China, Hong Kong, Singapore, Japan and Thailand.

The Malaysian plastics industry has been rated as among the most competitive in Asia. Globalization poses both challenges and opportunities simultaneously for Malaysian plastic manufacturers. Therefore, it is imperative for Malaysian manufacturers to sustain their competitiveness, through improved technologies, enhanced skills and penetrating new markets in developed and developing economies.[1]

Fiber crops have accompanied human society since the start of our time. In early history, humans collected the raw materials for ropes and textiles from the wild. Later societies learned to cultivate such crops. Plant fiber crops are among the earliest known cultivated plants and humans continued the domestication of these crops over millennia. Fiber crop varieties have been extensively developed through breeding and selection, according to societies' needs and values.

For instance, hemp and linen fragments were found in Neolithic sites in Syria, Turkey, Mesopotamia (present-day Iraq), and Persia (present-day Iran), and have been carbon dated back to 8000-6000 B.C. Fiber crops have been bred focusing on fiber quality, climatic adaptability, and yield factors. Ingenious fiber crops, such as flax, hemp, and nettle, possessed great agricultural importance for the production of textile fibers until the late 19th century. However, the mechanization of cotton harvest, processing, and development, and the growing demand for and production of cheap synthetic textile fibers destroyed the production of traditional fiber crops.

More recently, increasing environmental awareness, concern for environmental sustainability, and the growing global waste problem, initiation of ecological regulations and legislation such as the end-of-life vehicles regulation, the depletion of fossil fuels, and the increasingly higher price of crude oil have together created a groundswell of interest in renewable resources. Legislative pressure for greener technologies as well as customers' demands for more environmental friendly consumer goods are forcing materials suppliers and manufacturers to consider the environmental impact of their products at all stages of their life cycle, including materials selection processing, recycling, and final disposal. This and the worldwide availability of plant fibers and other abundantly accessible agro waste is responsible for this new research interest in the field of polymer science, engineering, and is responsible for a new interest in research in sustainable technology. Research has as its objective the development, processing, and manufacturing, recycling, and disposal of "green" plastics, adhesives, polymer composites, blends, and many other industrial products from renewable resources.

Renewable resources from agricultural or forestry products form a basis for new industrial products or alternative energy sources. Plant-based fibers are already used in a wide range of products. Plant fibers find applications as textiles and geotextiles, twines and ropes, special pups, insulating and padding materials, fleece, felts and nonwoven materials, and increasingly as reinforcement for polymers.

The mechanical properties of plant fibers are much lower when compared to those of the most widely used competing reinforcing glass fibers. However, because of their low density, the specific properties, (property-to-density ratio), strength, and stiffness of plant fibers are comparable to the values of glass fibers. The public generally regards products of renewable raw materials as environmental friendly. [2]

Traditional fiber-reinforced composites use various types of glass, carbon, aluminum oxide, and many others as reinforcing component. Natural fibers, especially bast (bark) fibers, such as flax, hemp, jute, henequen and many others were applied by some researchers as fiber reinforcement for composites in recent years. Advantages of natural fibers over man-made fibers include low density, low cost, recyclability and biodegradability. These advantages make natural fibers potential replacement for glass fibers in composite materials. Mechanical properties of natural fibers, especially flax, hemp, jute and sisal, are very good and may compete with glass fiber in specific strength and modulus. Figure 1.1 lists the mechanical properties of some natural and man-made fibers.

Table 1.1: Mechanical properties of natural fibers as compared to conventional reinforcing fibers.

Fiber	Density (g/cm^3)	Elongation (%)	Tensile strength (MPa)	Young's modulus (GPa)
Cotton	1.5–1.6	3.0–10.0	287–597	5.5–12.6
Jute	1.3–1.46	1.5–1.8	393–800	10–30
Flax	1.4–1.5	1.2–3.2	345–1500	27.6–80
Hemp	1.48	1.6	550–900	70
Ramie	1.5	2.0–3.8	220–938	44–128
Sisal	1.33–1.5	2.0–14	400–700	9.0–38.0
Coir	1.2	15.0–30.0	175–220	4.0–6.0
Softwood kraft	1.5	–	1000	40.0
E–glass	2.5	2.5–3.0	2000–3500	70.0
S–glass	2.5	2.8	4570	86.0
Aramide (normal)	1.4	3.3–3.7	3000–3150	63.0–67.0
Carbon (standard)	1.4	1.4–1.8	4000	230.0–240.0

Unfortunately, the performance of coir as a reinforcement in polymer composites is unsatisfactory and not comparable even with other natural fibers due to its low cellulose content (36–43%), high lignin content (41–45%) and high microfibrillar angle. Morphological studies of coir fibers show the outer sheath of lignin that develops the cellulose ultimate. The removal of this surface layer of lignin usually results in a better and more stable bond. [3]

The coir fibers are usually treated in order to improve resin-fiber interfacial bonding. Among the methods in improving the adhesive character of the coir fiber, alkaline treatment may be considered to be the most economical technique, the main disadvantage is the deterioration in the fiber strength during the treatment. [4]

Because of the above facts, alkali treatment and bleaching has been chosen as surface treatments for coir fibers in order to obtain better adhesion of the coir fibers with the epoxy resin in my research. The chemical and thermal property of coir fiber is determined by Kappa test and thermo gravimetric analysis respectively. Besides that, the mechanical property of the polymer which is tensile strength is determined. The improved fiber-matrix adhesion has been examined by scanning electron microscopy (SEM).

1.2 Problem Statement

Coir fiber have been reported to be as substitute for synthetic fiber reinforcements such as glass in plastics due to their low cost, low density, acceptable specific strength, good thermal insulation properties, reduced tool wear, reduced thermal and respiratory irritation and renewable resources. However, natural fibers are generally hydrophilic and are inherently incompatible with hydrophobic thermoplastics such as polypropylene (PP). Major problem of using natural fibers

with thermoplastics is the poor interfacial bonding between the fiber and thermoplastic. [5] This is due to presence of a layer of lignin and a small amount of oily layer at the outer surface of coir. [6]

This research is attempted to find the way how to improve the interfacial bonding between the coir fiber and the polymer itself and also to remove the layer of lignin and oily the layer through chemical modification or treatment in order to get a high quality fiber.

1.3 Objectives

The objectives of this study are:

(i) To modify the surface property of coir fiber.

(ii) Study the bonding mechanism between the coir fiber and the polymer.

1.4 Scope of Study

In order to achieve the objectives stated above, the following scopes of study have been planned:

(i) Surface treatment of fiber by NaOH solution with manipulated concentration.

(ii) Making composites with epoxy resin and characterizing of the composites.

1.5 Rationale and Significance

The ecologically relevant parameters provide some distinct advantages to the use of plant fiber crops. One of them is the plant fibers are of less concern to occupational health and safety during handling than other fibrous materials. The favorable aspect ratios and high specific properties at low cost make them an ecologically-friendly alternative to conventional reinforcing fibers in composite materials. The ecological character, the biodegradability, and the price of the plant fibers are very important for their acceptance in large volume engineering markets such as the automotive and construction industry. Innovative plant fiber-reinforced polymers are rapidly finding more and more applications in secondary structural applications especially for various applications in the automotive industry.

Plant fibers are currently used in considerable quantities in various applications in the automotive industry only in the interior of passenger cars and truck cabins. For example, fiber crops, such as flax and hemp, currently grown in the European Union (EU) and in North America provide an alternative to the overproduction of food crops and land division. The most important end user of natural fiber products in Europe is the automobile industry. Plant fibers are used as trim parts in door panels or cabin linings. Coir fibers bonded with natural latex are used as seat cushions. Plant fibers are increasingly used for thermo acoustic insulation purposes. These insulating materials are mainly based on recycled textiles and have high fiber content exceeding 80 wt%. At the present time, there are very few exterior parts made from plant fiber composites.

An increased demand for renewable resources, including plant fibers, as well as sources for energy or raw materials (reactants) for paints, lacquer, varnishes, adhesives, and polymers can have an important socioeconomic impact. It will generate a nonfood crop source for the economic development of farming and agricultural-based areas of the world.

Natural fiber-reinforced composites can be applied in the plastics, automobile and packaging industries to cut down on material cost. A better understanding of the chemical composition and surface adhesive bonding of natural fiber is necessary for developing natural fiber-reinforced composites. The components of natural fibers include cellulose, hemicellulose, lignin, pectin, waxes and water soluble substances. [7]

CHAPTER 2

LITERATURE REVIEW

2.1 History of Biopolymer

Composite materials are attractive because they combine material properties in ways not found in nature. Such materials often result in lightweight structures having high stiffness and tailored properties for specific applications, thereby saving weight and reducing energy needs. Fiber-reinforced plastic composites began with cellulose fiber in phenolics in 1908, later extending to urea and melamine, and reaching commodity status in the 1940s with glass fiber in unsaturated polyesters. From guitars, tennis racquets, and cars to microlight aircrafts, electronic components, and artificial joints, composites are finding use in diverse fields.

The fiber-reinforced composites market is a multibillion-dollar business. Glass fiber is the dominant fiber and is used in 95% of cases to reinforced thermoplastic and thermoset composites. Current research findings show that in certain composite applications, natural fibers demonstrate competitive performance to glass fibers.

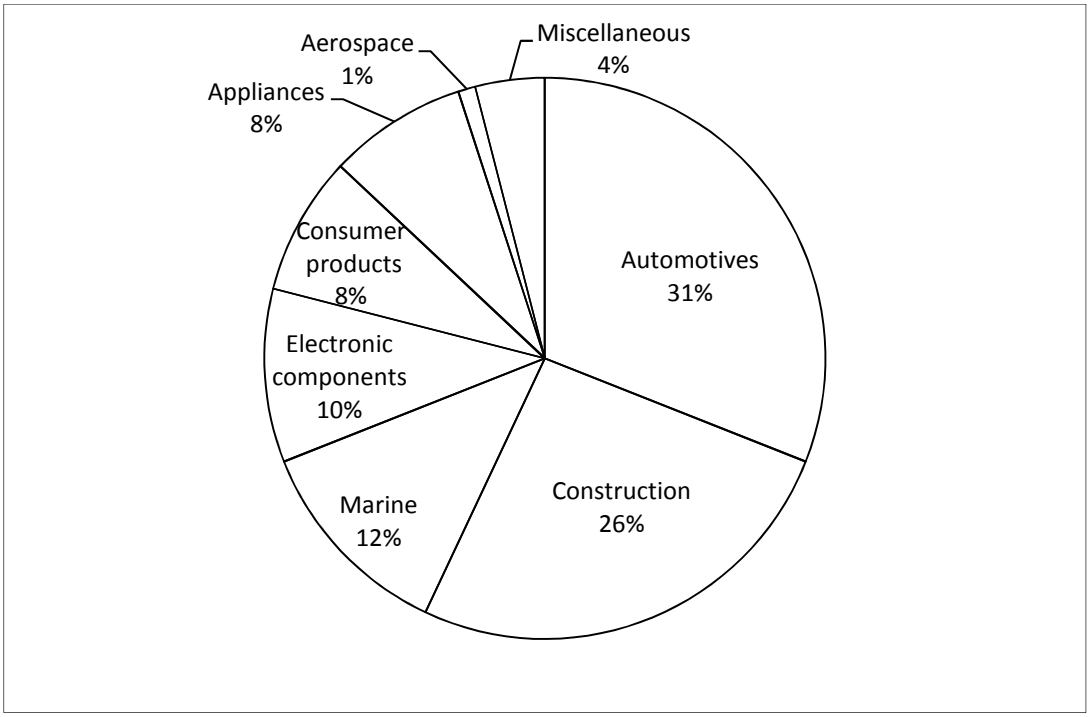

Figure 2.1: Fiber-reinforced plastic composites used in 2002. (Adapt from *Plast. News.* August 26, 2002)

After decades of development of high-performance artificial fibers like carbon, aramid, and glass, natural fibers have gained renewed interest, especially as a glass fiber substitute in automotive industries. Advantages of natural fibers over synthetic or man-made fibers such as glass and carbon are as follows: low cost, low density, acceptable specific strength properties, ease of separation, carbon dioxide sequestration, and biodegradability. Natural fiber composites are now emerging as realistic alternative to wood-filled and glass-reinforced plastics. Ecofreindly biocomposites have the potential to be the new material of the 21st century and be a partial solution to many global environmental problems. [8]

2.2 General Review of Coir Fiber

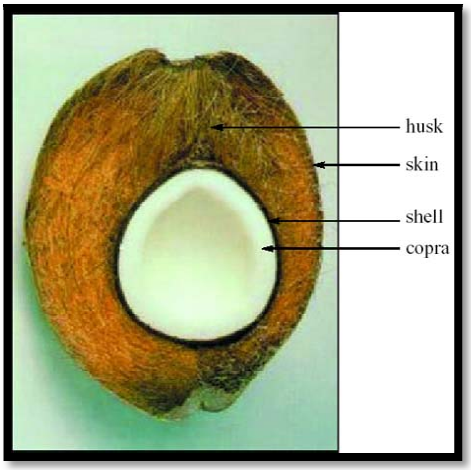

Figure 2.2: Cross section of a coconut palm

Coir (*Cocos nucifera*, Palmae) fibers are obtained from the fibrous husk (mesocarp) encasing the fruit of the coconut palm (Figure 2.3), which is a by-product of the copra extraction process. The term *coir* is derived from kayar, a rope or cord, and from kayaru, meaning to be twisted. Coconut palms are cultivated throughout tropical countries mostly for the high oil content of the endosperm (copra). The oil is widely used in both the food and nonfood industries. Large production areas are found along the coastal regions in the wet tropical area of Asia in the Philippines, Indonesia, India, Sri Lanka, and Malaysia. [2]

Figure 2.3: Photograph of a *Cocos nucifera* palm with coconuts.

In these countries millions of people make a living from coconut palm and its many products. However, India and Sri Lanka are the main producing countries of coir fiber. On average, from 100 coconuts 7.5 to 8.2 kg of coir fibers can be obtained. After separation of the nut manually from the husk, the fibrous husk can be processed by variety of retting techniques, but traditionally this takes place in ponds of brackish water (for 3 to 6 months), in salt backwaters, or in lagoons. Saltwater retting requires 10 to 12 months. Traditional water-retting procedures result in highly polluted waters and the accumulation of large chucks of coir pith. During the retting of the husks, the coir fibers are softened and can be easily decorticated and extracted by beating. After hackling, washing, and drying, the fibers are loosened manually and further cleaned. Afterwards the fibers are separated into bristle fibers (~20 to 40 cm long), by combing, and mattress fibers, which are random fibers having a length of 2 to 10 cm. The diameter of coir fibers varies between 0.1 and 1.5mm. [2]

Better grade coir fibers are light in color, but the color ranges from golden yellow for fibers obtained from not completely ripened nuts to reddish-brown from ripe nuts. Individual coir fibers are quite short, about 500 μm in length. The cells are thick walled, having an irregular lumen. The fiber surface is covered with cavities arising from dried out sieve cells. [9]

Coir fibers have high lignin but low cellulose content, as a result of which the fibers are resilient, strong, and highly durable. Coir is one of the toughest plant fibers available. It does not pill and is highly abrasion and rot (fungal and bacterial) resistant. Furthermore, coir is naturally insulating and sound absorbing, antistatic, and difficult to ignite. Due to the ability of coir fibers to tolerate water immersion for months without disintegrating, they find many applications as horticultural and erosion control products (geotextiles). Coir fibers are the only fruit fiber that is used in the textile industry. They are widely used as seat cushions in the automotive industry because of their high rate of moisture absorption. [10]

2.3 Introduction to Fiber Chemistry

All natural fibers, whether wood or nonwood types, are cellulosic in nature. The major constituents of natural biofibers are cellulose and lignin. The amount of cellulose, in lignocellulosic systems, can vary depending on the species and the age of the plant. [8]

The chemical composition as well as the structure of plant fibers is fairly complicated. Plant fibers are a composite material designed by nature. The fibers are basically a rigid, crystalline cellulose microfibril-reinforced amorphous lignin and/or hemicelluloses matrix. Most plant fibers, except for cotton, are composed of cellulose, hemicelluloses, lignin, waxes, and some water-soluble compounds. [2]

Lignocellulosic is a hygroscopic material that absorb water when expose to wet condition. Besides that, lignocellulosic can be recycled naturally with biological degradation, heat, aqueous, photochemical, chemical and mechanical. In other words, lignocellulosic is generated naturally from carbon dioxide, water, and contain compound that allowing them to be recycled to its basic compound. [11]

Table 2.1: Chemical Composition, and Moisture Content of Vegetable Fibers

Fiber	Cellulose (wt%)	Hemicelluloses (wt%)	Lignin (wt%)	Pectin (wt%)	Moisture Content (wt%)	Waxes (wt%)	Microfibrillar Angle (deg)
Flax	71	18.6–20.6	2.2	2.3	8–12	1.7	5–10
Hemp	70–74	17.9–22.4	3.7–5.7	0.9	6.2–12	0.8	2–6.2
Jute	61–71.5	13.6–20.4	12–13	0.2	12.5–13.7	0.5	8
Kenaf	45–57	21.5	8–13	3–5			
Ramie	68.6–76.2	13.1–16.7	0.6–0.7	1.9	7.5–17	0.3	7.5
Nettle	86				11–17		
Sisal	66–78	10–14	10–14	10	10–22	2	10–22
Henequen	77.6	4–8	13.1				
PALF	70–82		5–12.7		11.8		14
Banana	63–64	10	5		10–12		
Abaca	56–63		12–13	1	5–10		
Oil palm EFB	65		19				42
Oil palm mesocarp	60		11				46
Cotton	85–90	5.7		0–1	7.85–8.5	0.6	—
Coir	32–43	0.15–0.25	40–45	3–4	8		30–49

Source: (Bismarck A. et al., 2005)